GEOPHYSICAL SURVEY
GROUND WATER EVALUATION
TMK 8-7-14:02
ISLAND OF HAWAII

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GROUND WATER EVALUATION
TMK 8-7-14:02
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Prepared For:

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(Our Job #90024)

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1.0 INTRODUCTION

This report contains the results of time domain electromagnetic (TDEM) measurements acquired on April 27, 1990, on property owned by Cal-Pacific International, Inc. (TMK 8-7-14:02) on the Island of Hawaii. The data was acquired by Blackhawk Geosciences, Inc. at two locations as shown in Figure 1-1 using a Geonics EM-37 transient system. The specifications of the EM-37 and a brief technical note describing the basic theory of TDEM are given in Appendix A.

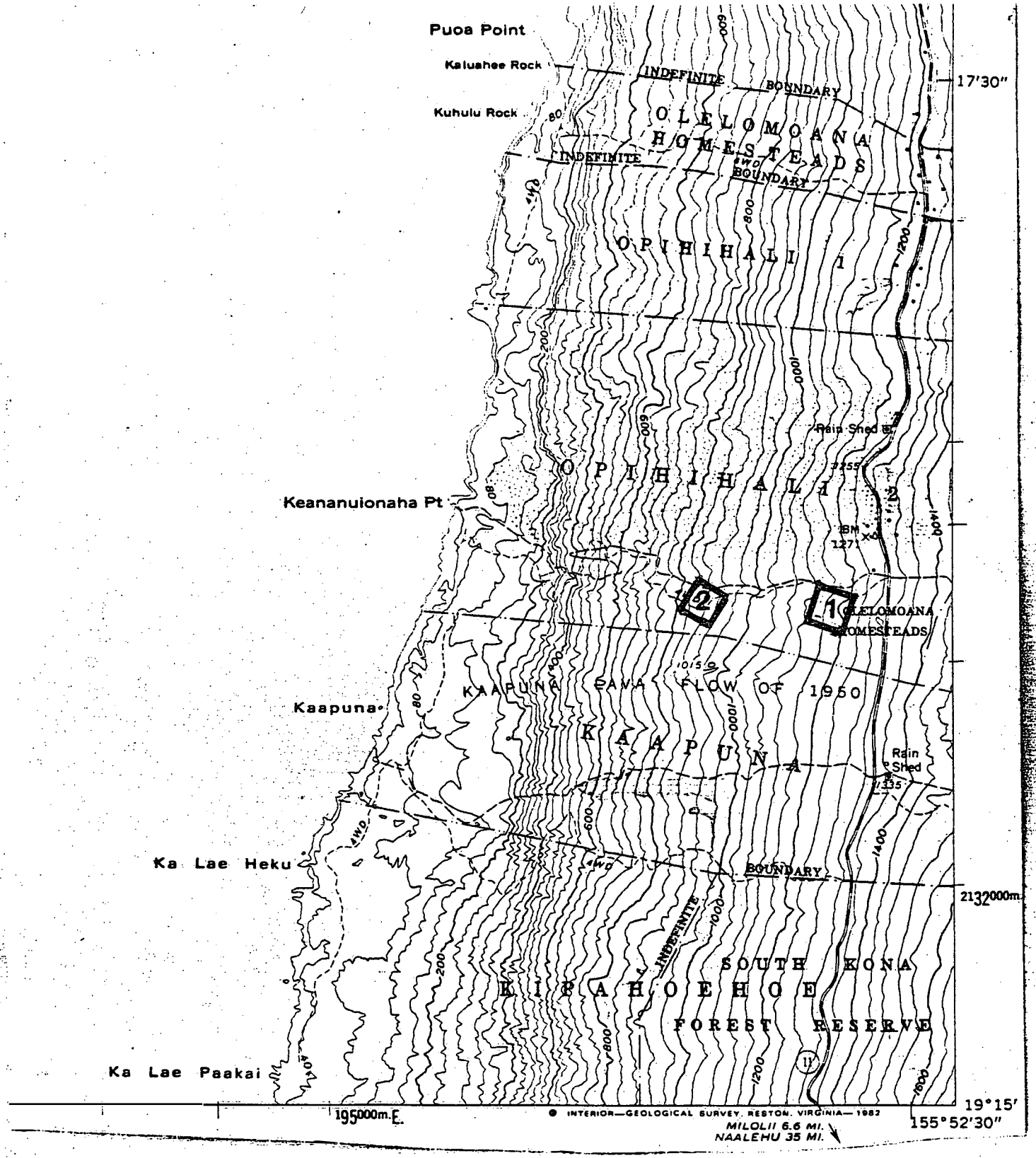
The objective of the geophysical survey can be explained with the use of Figure 1-2 which shows the schematic hydro-geologic section often encountered in volcanic islands. In this figure, ground water is shown in two main occurrences:

(1) In the basal mode the fresh water lies in static equilibrium on top of the basal saline water. In this case the Ghyben-Herzberg relation states that for every foot that the fresh water is elevated above sea level, there will be 40 ft of fresh water below sea level.

(2) Typically, further inland, ground water occurrences are often controlled by geologic structures such as dikes or other intrusives. In these cases ground water heads and production can be quite variable.

On the property owned by Cal-Pacific International, Inc. the main ground water occurrence is expected to be in the basal mode. For basal mode water exploration, geophysical methods which measure the electrical resistivity of the subsurface are very effective. The reason for this is that electrical resistivity is directly influenced by changes in ground water salinity. By measuring the depth to saline water an estimate of the fresh water resource can be made (i.e., approximately the volume between sea level and the elevation of the saline water).

The TDEM method was selected for this survey because it has the best sensitivity to lateral and vertical changes in resistivity compared to other geophysical methods.



TDEM Transmitter Loop

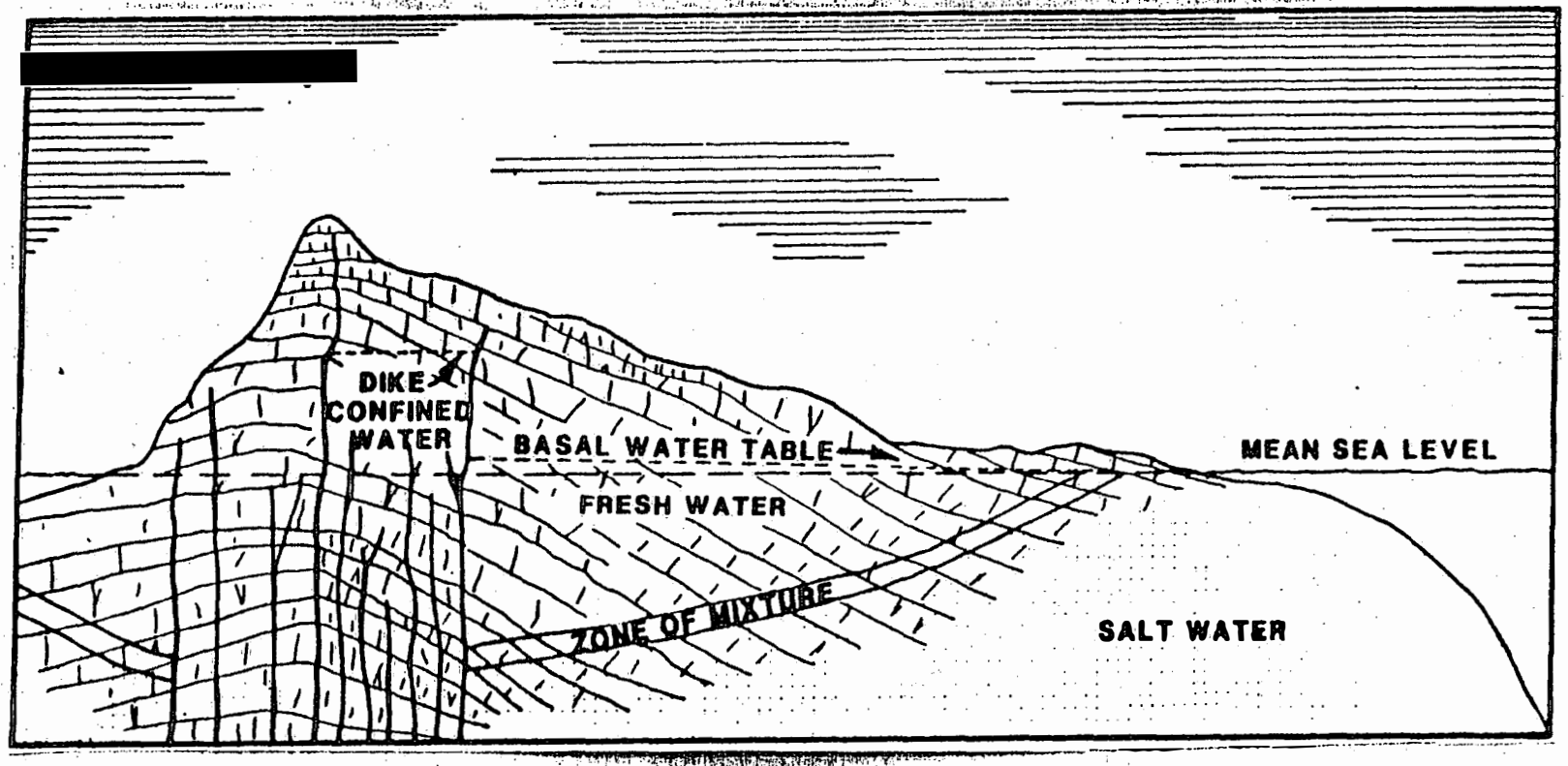
2000 1000 0 1000 2000

SCALE - FEET

BLACKHAWK GEOSCIENCES, INC.

GEOPHYSICAL SURVEY
LOCATION MAP
CAL-PACIFIC INTERNATIONAL, INC.
TMK 8-7-14:02, HAWAII

PROJECT NO.: 90024 **FIGURE 1-1**



BLACKHAWK GEOSCIENCES, INC.

SCHEMATIC HYDRO-GEOLOGIC CROSS SECTION

CAL-PACIFIC INTERNATIONAL, INC.

TMK 8-7-14:02, HAWAII

PROJECT NO.: 90024 FIGURE 1-2

2.0 RESULTS AND CONCLUSIONS

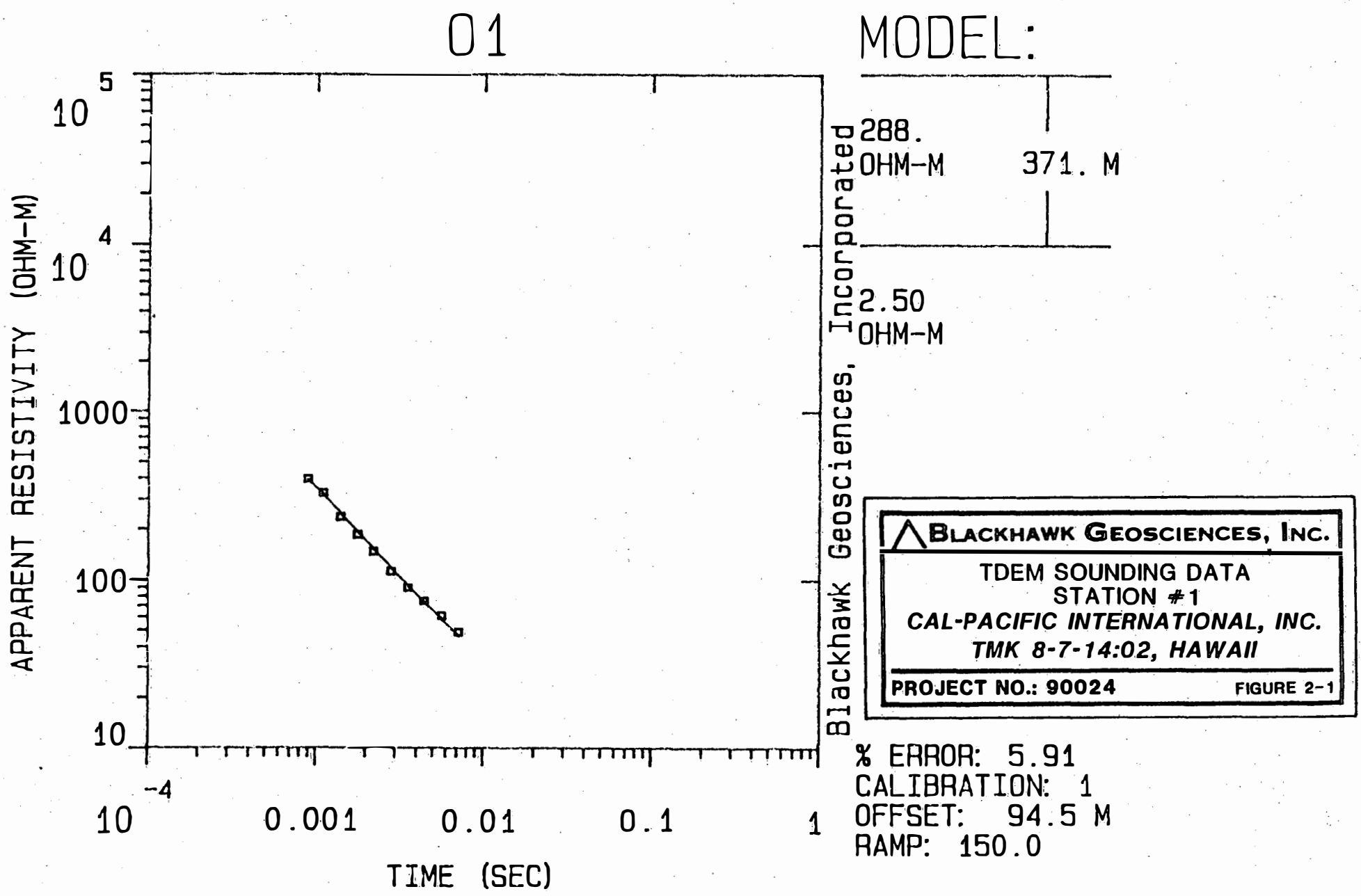
The two measurements taken were interpreted into layered resistivity sections with an Automatic Ridge Regression Transient Inversion routine. The results of these interpretations are given in Figures 2-1 through 2-4. For example, for sounding #1 in Figure 2-1 the field data (small squares) are superimposed on a solid line. The solid line represents the best fit inversion model. The model results are shown on the right, and in this case a two-layered section with an upper layer of 288 ohm-m and thickness of 371 m, overlies a low resistivity (2.50 ohm-m) layer. The upper layer is interpreted as dry volcanics and the basement layer is interpreted as saline-saturated volcanics. In Figure 2-2 the data sheet for sounding #1 is given. This figure shows the data values, percent error between the model and the data, the model parameters, and some of the instrument set-up parameters.

In Table 2-1 below the interpretations are summarized.

Table 2-1. Summary of TDEM results (TMK 8-7-14:02)

Sounding #	Surface Elevation (ft)	Interpreted Depth to Saline Water (ft)	Elevation of Saline Water (ft)
1	1180	1218	-38
2	880	888	-8

The accuracy of interpretation is expected to be approximately ± 5% in depth to the saline water. For both soundings saline water is interpreted very close to sea level. This indicates a small thickness of non-saline water resources, and this small thickness may imply that the water resource likely is brackish.


01
MODEL:
288.
OHM-M
371. M
2.50
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
Blackhawk Geosciences, Incorporated
BLACKHAWK GEOSCIENCES, INC.
TDEM SOUNDING DATA
STATION #1
CAL-PACIFIC INTERNATIONAL, INC.
TMK 8-7-14:02, HAWAII
PROJECT NO.: 90024
FIGURE 2-1
% ERROR: 5.91
CALIBRATION: 1
OFFSET: 94.5 M
RAMP: 150.0

01

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		359.7	1180.0		
288.33	371.4	-11.8	-38.6	1.3	1.3
2.50					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	3.95E+02	3.90E+02	1.308	
2	1.10E-03	3.26E+02	3.18E+02	2.554	
3	1.40E-03	2.37E+02	2.47E+02	-3.951	
4	1.77E-03	1.85E+02	1.92E+02	-3.376	
5	2.20E-03	1.47E+02	1.52E+02	-2.949	
6	2.80E-03	1.12E+02	1.17E+02	-4.332	
7	3.55E-03	8.98E+01	9.16E+01	-1.876	
8	4.43E-03	7.49E+01	7.30E+01	2.527	
9	5.64E-03	6.09E+01	5.75E+01	6.013	
10	7.13E-03	4.88E+01	4.59E+01	6.335	

R: 94. X: 0. Y: 95. DL: 189. REQ: 106. CF: 1.0000
TDHZ ARRAY, 10 DATA POINTS, RAMP: 150.0 MICROSEC, DATA: 01
2704 001N 001E Z OPR XTL L 5 8+100
Ch.21 = 0.15 Ch.22 = 0.89 Ch.23 = 19 Ch.24 = 35
RMS LOG ERROR: 2.49E-02, ANTILOG YIELDS 5.9054 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

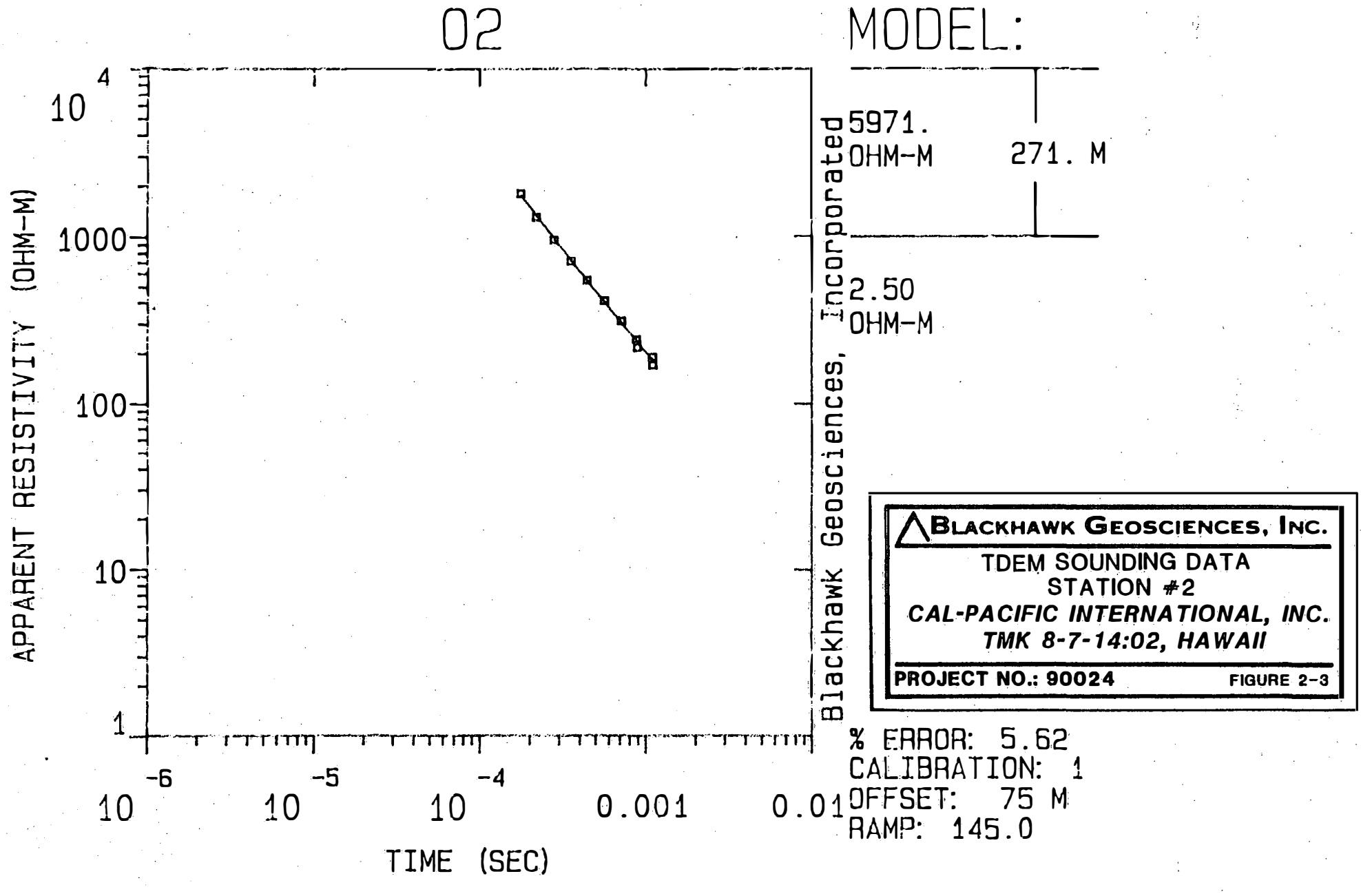
PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00		
F 2	0.00	0.00	
T 1	0.00	0.00	1.00
	P 1	F 2	T 1

BLACKHAWK GEOSCIENCES, INC.

TDEM SOUNDING DATA
STATION #1
CAL-PACIFIC INTERNATIONAL, INC.
TMK 8-7-14:02, HAWAII

PROJECT NO.: 90024 **FIGURE 2-2**


02
MODEL:
5971.
OHM-M
271. M
2.50
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-6
10^-5
10^-4
0.001
0.01
TIME (SEC)
Blackhawk Geosciences, Incorporated
BLACKHAWK GEOSCIENCES, INC.
TDEM SOUNDING DATA
STATION #2
CAL-PACIFIC INTERNATIONAL, INC.
TMK 8-7-14:02, HAWAII
PROJECT NO.: 90024
FIGURE 2-3
% ERROR: 5.62
CALIBRATION: 1
OFFSET: 75 M
RAMP: 145.0

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		268.2	880.0		
5970.95	270.6	-2.4	-7.9	0.0	0.0
2.50					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.77E-04	1.80E+03	1.77E+03	2.011	
2	2.20E-04	1.30E+03	1.32E+03	-1.422	
3	2.80E-04	9.51E+02	9.66E+02	-1.472	
4	3.55E-04	7.09E+02	7.12E+02	-0.415	
5	4.43E-04	5.44E+02	5.39E+02	1.050	
6	5.64E-04	4.12E+02	4.00E+02	3.010	
7	7.13E-04	3.12E+02	3.01E+02	3.546	
8	8.81E-04	2.41E+02	2.34E+02	3.064	
9	8.90E-04	2.16E+02	2.31E+02	-6.675	
10	1.10E-03	1.89E+02	1.82E+02	4.228	
11	1.10E-03	1.70E+02	1.81E+02	-6.271	

R: 75. X: 0. Y: 75. DL: 150. REQ: 83. CF: 1.0000
TDHZ ARRAY, 11 DATA POINTS, RAMP: 145.0 MICROSEC, DATA: 02
2704 001N 001W Z OPR XTL H 4 8+100
Ch.21 = 0.145 Ch.22 = 0.089 Ch.23 = 22 Ch.24 =
RMS LOG ERROR: 2.38E-02, ANTILOG YIELDS 5.6236 %
LATE TIME PARAMETERS

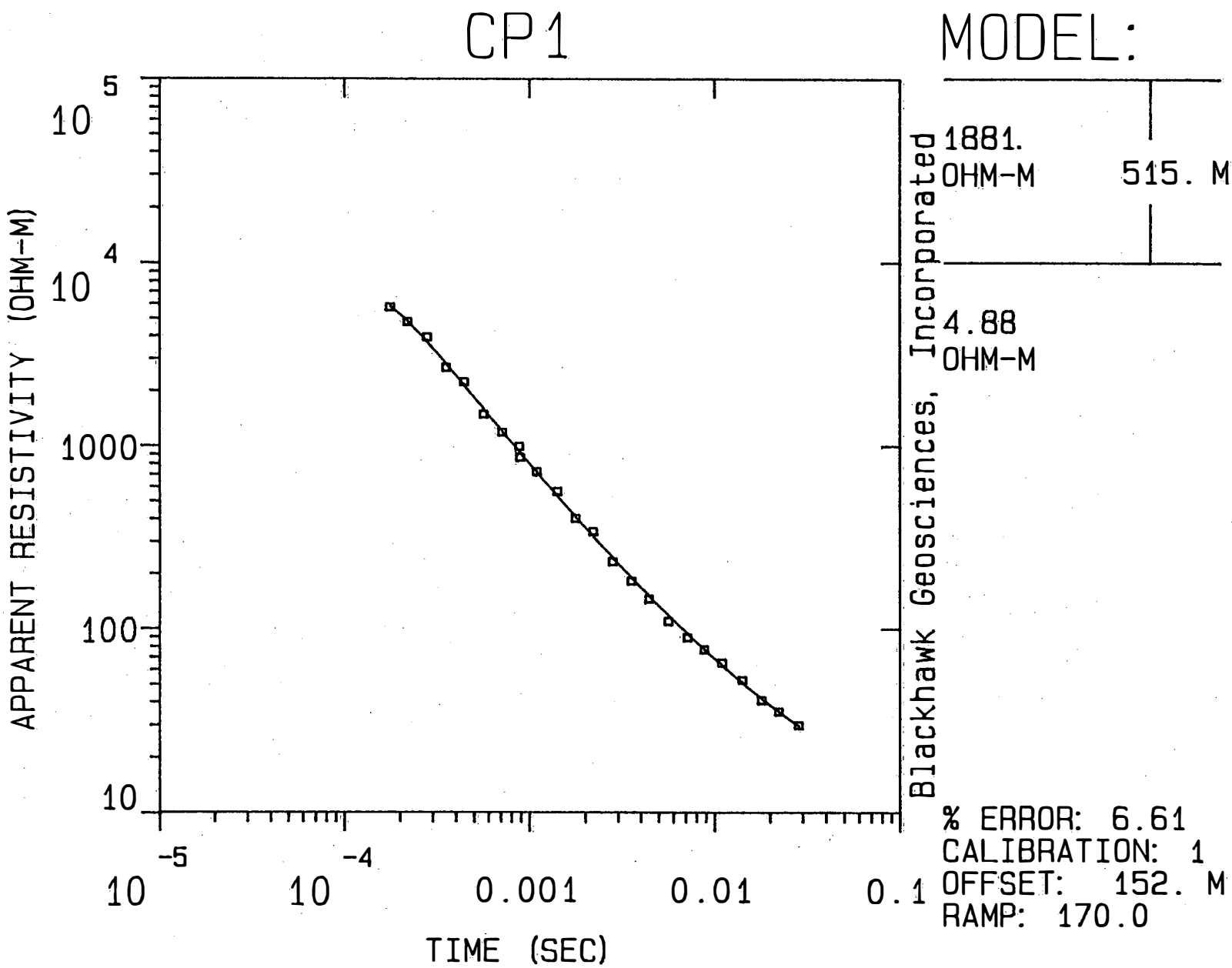
* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.16
F 2 0.00 0.00
T 1 0.00 0.00 1.00
P 1 F 2 T 1

BLACKHAWK GEOSCIENCES, INC.

TDEM SOUNDING DATA
STATION #2
CAL-PACIFIC INTERNATIONAL, INC.
TMK 8-7-14:02; HAWAII

PROJECT NO.: 90024 **FIGURE 2-4**


CP1
MODEL:
1881.
OHM-M
515. M
4.88
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 6.61
CALIBRATION: 1
OFFSET: 152. M
RAMP: 170.0

CP1

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		445.0	1460.0		
1881.22	515.2	-70.2	-230.3	0.3	0.3
4.88					

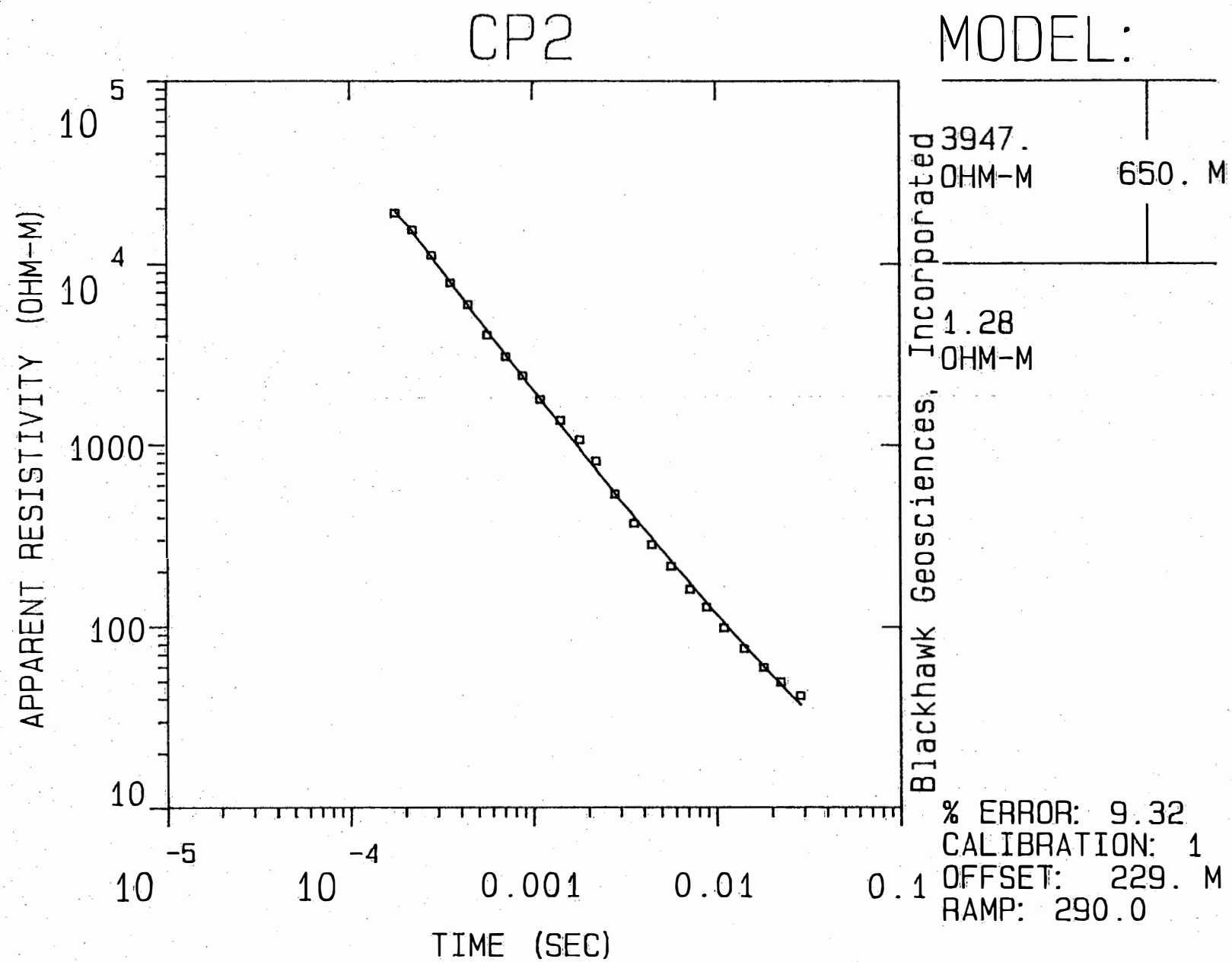
	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.77E-04	5.71E+03	5.79E+03	-1.281	
2	2.20E-04	4.77E+03	4.79E+03	-0.247	
3	2.80E-04	3.92E+03	3.69E+03	6.364	
4	3.55E-04	2.68E+03	2.79E+03	-3.933	
5	4.43E-04	2.23E+03	2.13E+03	5.041	
6	5.64E-04	1.49E+03	1.58E+03	-5.967	
7	7.13E-04	1.18E+03	1.19E+03	-0.554	
8	8.81E-04	9.89E+02	9.23E+02	7.177	
9	8.90E-04	8.63E+02	9.11E+02	-5.294	
10	1.10E-03	7.23E+02	7.12E+02	1.587	
11	1.41E-03	5.65E+02	5.29E+02	6.724	
12	1.77E-03	4.02E+02	4.08E+02	-1.400	
13	2.20E-03	3.41E+02	3.19E+02	6.806	
14	2.80E-03	2.33E+02	2.44E+02	-4.558	
15	3.55E-03	1.82E+02	1.89E+02	-3.787	
16	4.43E-03	1.45E+02	1.50E+02	-3.082	
17	5.64E-03	1.10E+02	1.18E+02	-6.761	
18	7.13E-03	8.95E+01	9.35E+01	-4.220	
19	8.81E-03	7.70E+01	7.66E+01	0.535	
20	1.10E-02	6.54E+01	6.29E+01	3.926	
21	1.41E-02	5.27E+01	5.06E+01	4.130	
22	1.80E-02	4.11E+01	4.16E+01	-1.304	
23	2.22E-02	3.55E+01	3.53E+01	0.745	
24	2.85E-02	3.00E+01	2.95E+01	1.672	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 24 DATA POINTS, RAMP: 170.0 MICROSEC, DATA: CP1
2304 001N 001E Z OPR XTL H 6 8+100
Ch.21 = 0.17 Ch.22 = 0.089 Ch.23 = 16 Ch.24 = 9
RMS LOG ERROR: 2.78E-02, ANTILOG YIELDS 6.6071 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.91		
P 2	-0.03	0.93	
T 1	0.00	0.00	1.00


CP2
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
3947.
OHM-M
650. M
1.28
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 9.32
CALIBRATION: 1
OFFSET: 229. M
RAMP: 290.0

CP2

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		536.4	1760.0		
3946.61	650.0	-113.6	-372.7	0.2	0.2
1.28					

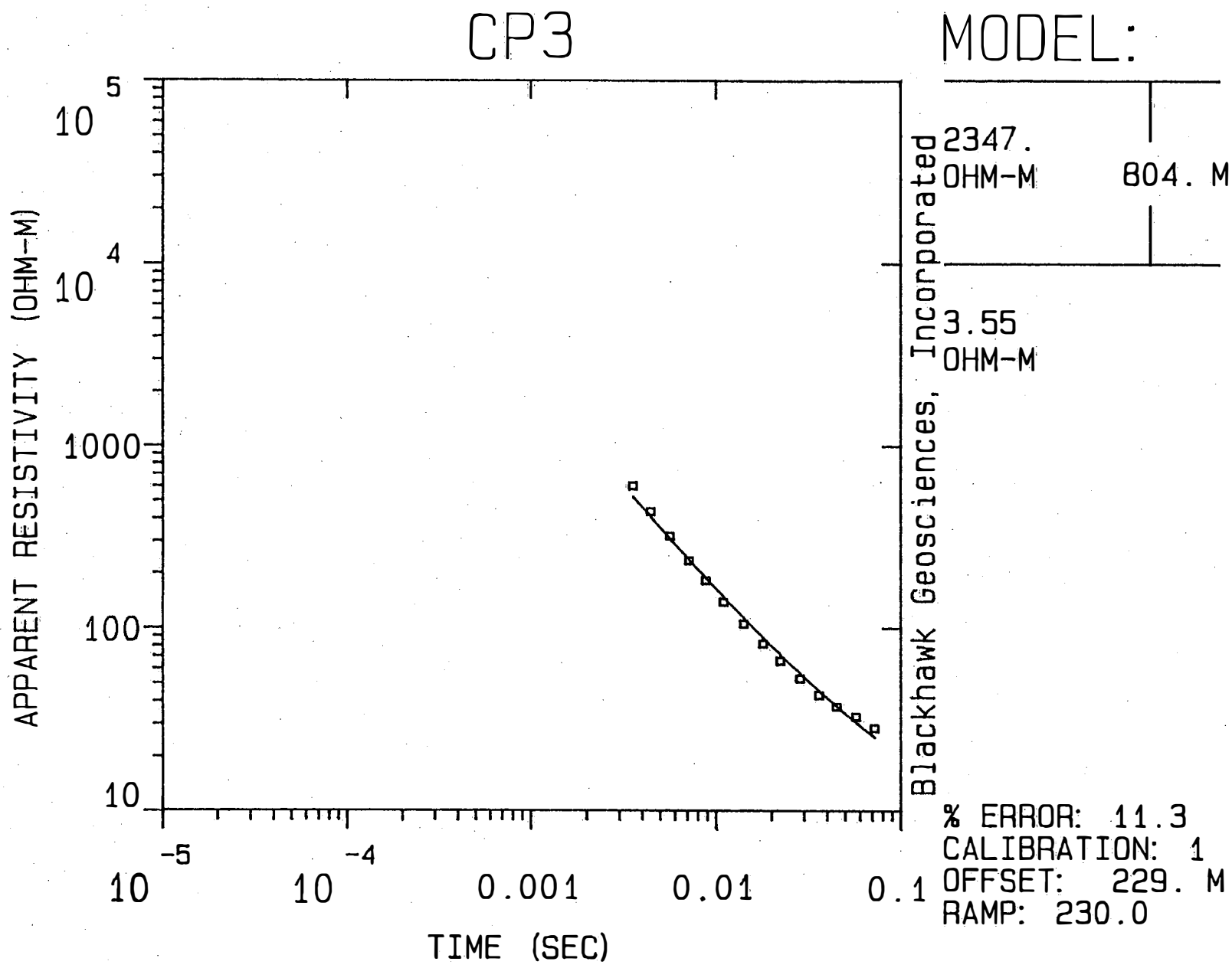
	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.77E-04	1.88E+04	1.93E+04	-2.195	
2	2.20E-04	1.53E+04	1.49E+04	3.087	
3	2.80E-04	1.12E+04	1.09E+04	2.757	
4	3.55E-04	7.88E+03	7.90E+03	-0.281	
5	4.43E-04	5.97E+03	5.87E+03	1.752	
6	5.64E-04	4.05E+03	4.25E+03	-4.766	
7	7.13E-04	3.07E+03	3.12E+03	-1.630	
8	8.81E-04	2.41E+03	2.36E+03	1.948	
9	1.10E-03	1.78E+03	1.78E+03	0.139	
10	1.41E-03	1.36E+03	1.28E+03	6.256	
11	1.80E-03	1.07E+03	9.43E+02	13.011	
12	2.20E-03	8.12E+02	7.29E+02	11.463	
13	2.80E-03	5.37E+02	5.39E+02	-0.301	
14	3.55E-03	3.71E+02	4.01E+02	-7.525	
15	4.43E-03	2.82E+02	3.06E+02	-7.719	
16	5.64E-03	2.15E+02	2.28E+02	-5.983	
17	7.13E-03	1.60E+02	1.73E+02	-7.188	
18	8.81E-03	1.28E+02	1.35E+02	-4.776	
19	1.10E-02	9.86E+01	1.05E+02	-5.896	
20	1.41E-02	7.59E+01	7.88E+01	-3.561	
21	1.80E-02	5.98E+01	6.04E+01	-1.020	
22	2.22E-02	4.98E+01	4.80E+01	3.694	
23	2.85E-02	4.18E+01	3.70E+01	12.777	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
CLHZ ARRAY, 23 DATA POINTS, RAMP: 290.0 MICROSEC, DATA: CP2
2404 001N 002E Z OPR XTL H 5 8+100
Ch.21 = 0.29 Ch.22 = 0.089 Ch.23 = 14.5 Ch.24 =
RMS LOG ERROR: 3.87E-02, ANTILOG YIELDS 9.3189 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.66		
P 2	-0.16	0.67	
T 1	-0.01	-0.03	1.00


CP3
MODEL:
2347.
OHM-M
804. M
3.55
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 11.3
CALIBRATION: 1
OFFSET: 229. M
RAMP: 230.0

CP3

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		673.6	2210.0		
2347.39	804.3	-130.7	-428.7	0.3	0.3
3.55					

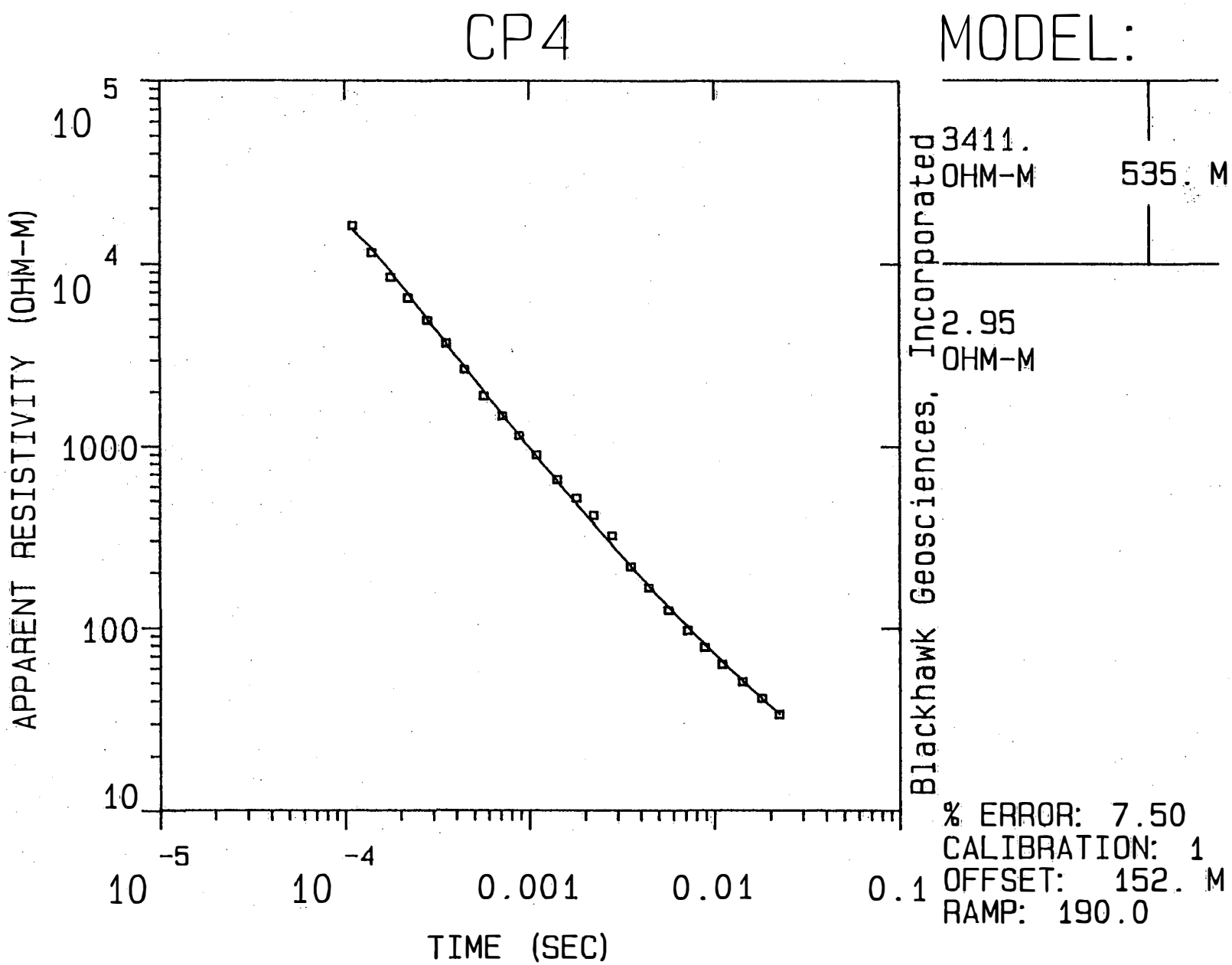
	TIMES	DATA	CALC	% ERROR	STD ERR
1	3.55E-03	6.02E+02	5.25E+02	14.643	
2	4.43E-03	4.34E+02	4.06E+02	7.003	
3	5.64E-03	3.19E+02	3.07E+02	3.900	
4	7.13E-03	2.34E+02	2.35E+02	-0.809	
5	8.81E-03	1.81E+02	1.86E+02	-2.744	
6	1.10E-02	1.38E+02	1.47E+02	-5.774	
7	1.41E-02	1.05E+02	1.13E+02	-6.842	
8	1.80E-02	8.15E+01	8.79E+01	-7.196	
9	2.22E-02	6.58E+01	7.11E+01	-7.513	
10	2.85E-02	5.28E+01	5.61E+01	-5.918	
11	3.60E-02	4.30E+01	4.52E+01	-4.794	
12	4.49E-02	3.72E+01	3.73E+01	-0.348	
13	5.70E-02	3.28E+01	3.05E+01	7.805	
14	7.19E-02	2.84E+01	2.53E+01	12.476	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
CLHZ ARRAY, 14 DATA POINTS, RAMP: 230.0 MICROSEC, DATA: CP3
2504 001N 003E Z OPR XTL L 6 10+1000
Ch.21 = 0.23 Ch.22 = 0.89 Ch.23 = 14 Ch.24 = 20
RMS LOG ERROR: 4.65E-02, ANTILOG YIELDS 11.3078 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.06		
P 2	-0.02	0.91	
T 1	0.01	0.00	1.00


CP4
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
3411.
OHM-M
535. M
2.95
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 7.50
CALIBRATION: 1
OFFSET: 152. M
RAMP: 190.0

CP4

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		451.1	1480.0		
3411.42	534.6	-83.5	-273.9	0.2	0.2
2.95					

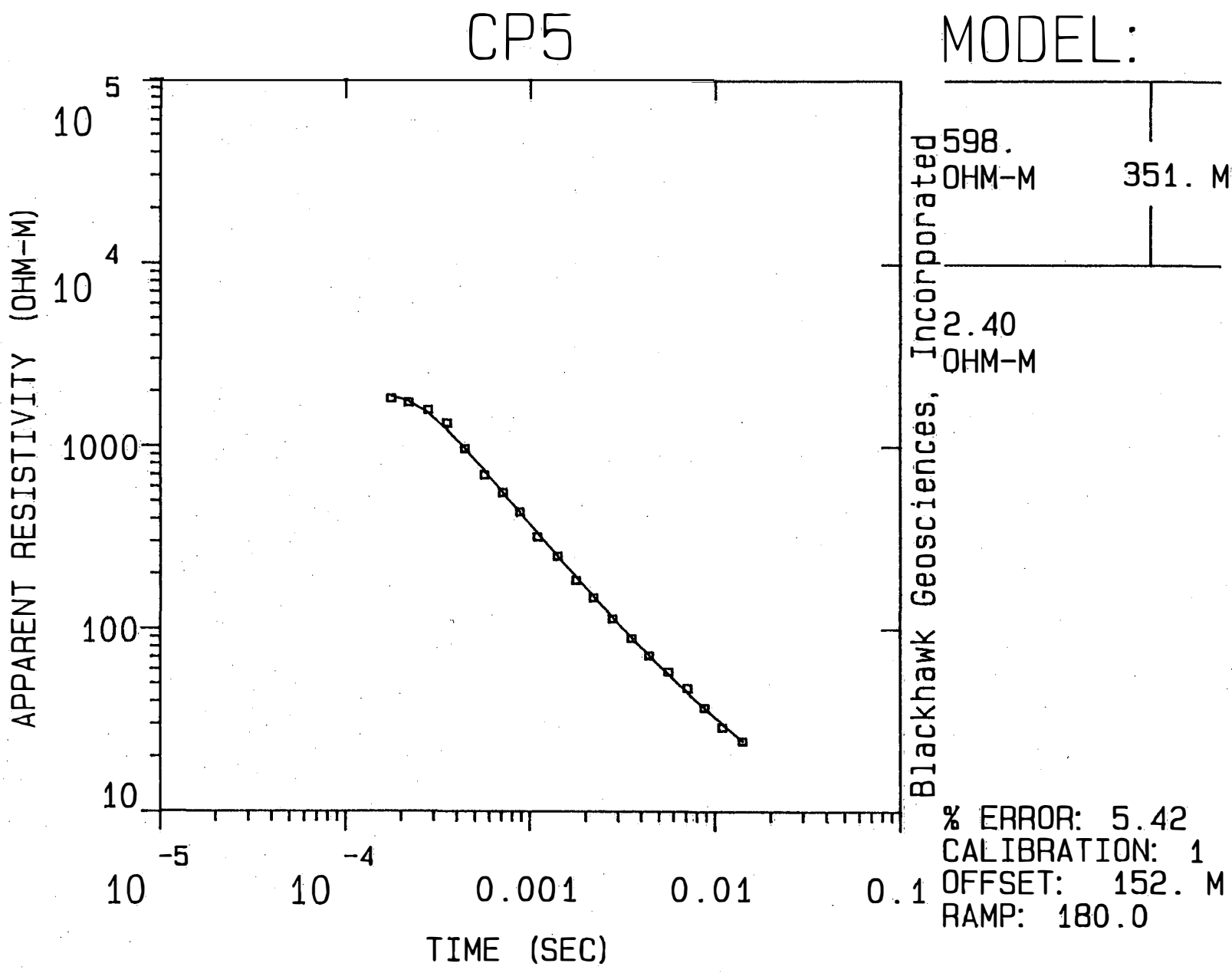
	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	1.61E+04	1.54E+04	4.829	
2	1.40E-04	1.15E+04	1.20E+04	-4.240	
3	1.77E-04	8.47E+03	9.05E+03	-6.464	
4	2.20E-04	6.51E+03	6.84E+03	-4.764	
5	2.80E-04	4.93E+03	4.99E+03	-1.159	
6	3.55E-04	3.71E+03	3.66E+03	1.320	
7	4.43E-04	2.67E+03	2.75E+03	-2.727	
8	5.64E-04	1.91E+03	2.01E+03	-5.304	
9	7.13E-04	1.48E+03	1.49E+03	-1.252	
10	8.81E-04	1.15E+03	1.15E+03	0.248	
11	1.10E-03	8.98E+02	8.73E+02	2.808	
12	1.41E-03	6.57E+02	6.41E+02	2.445	
13	1.80E-03	5.18E+02	4.79E+02	8.127	
14	2.22E-03	4.16E+02	3.72E+02	11.978	
15	2.80E-03	3.20E+02	2.84E+02	12.860	
16	3.55E-03	2.16E+02	2.16E+02	-0.219	
17	4.43E-03	1.65E+02	1.69E+02	-2.147	
18	5.64E-03	1.25E+02	1.30E+02	-3.595	
19	7.13E-03	9.72E+01	1.01E+02	-3.854	
20	8.81E-03	7.86E+01	8.12E+01	-3.314	
21	1.10E-02	6.33E+01	6.53E+01	-3.097	
22	1.41E-02	5.08E+01	5.12E+01	-0.729	
23	1.80E-02	4.15E+01	4.10E+01	1.081	
24	2.22E-02	3.38E+01	3.40E+01	-0.444	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 24 DATA POINTS, RAMP: 190.0 MICROSEC, DATA: CP4
0105 001N 004E Z OPR XTL L 6 10+1000
Ch.21 = 0.19 Ch.22 = 0.89 Ch.23 = 17 Ch.24 = 92
RMS LOG ERROR: 3.14E-02, ANTILOG YIELDS 7.4952 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.86		
P 2	-0.07	0.85	
T 1	0.00	-0.01	1.00


CP5
MODEL:
598.
OHM-M
351. M
2.40
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 5.42
CALIBRATION: 1
OFFSET: 152. M
RAMP: 180.0

CP5

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		347.5	1140.0		
597.70	350.8	-3.3	-10.9	0.6	0.6
2.40					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.77E-04	1.83E+03	1.89E+03	-2.900	
2	2.20E-04	1.74E+03	1.76E+03	-0.903	
3	2.80E-04	1.58E+03	1.51E+03	4.453	
4	3.55E-04	1.34E+03	1.22E+03	9.266	
5	4.43E-04	9.67E+02	9.65E+02	0.133	
6	5.64E-04	6.97E+02	7.31E+02	-4.660	
7	7.13E-04	5.57E+02	5.54E+02	0.592	
8	8.81E-04	4.37E+02	4.31E+02	1.187	
9	1.10E-03	3.18E+02	3.32E+02	-4.317	
10	1.41E-03	2.50E+02	2.49E+02	0.265	
11	1.77E-03	1.84E+02	1.92E+02	-4.181	
12	2.20E-03	1.48E+02	1.51E+02	-1.785	
13	2.80E-03	1.14E+02	1.16E+02	-1.658	
14	3.55E-03	8.86E+01	8.96E+01	-1.063	
15	4.43E-03	7.13E+01	7.11E+01	0.288	
16	5.64E-03	5.81E+01	5.57E+01	4.204	
17	7.13E-03	4.72E+01	4.44E+01	6.295	
18	8.81E-03	3.67E+01	3.64E+01	1.001	
19	1.10E-02	2.87E+01	2.99E+01	-3.895	
20	1.41E-02	2.42E+01	2.41E+01	0.389	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 20 DATA POINTS, RAMP: 180.0 MICROSEC, DATA: CP5
0405 004N 001E Z OPR XTL H 6 8+100
Ch.21 = 0.18 Ch.22 = 0.089 Ch.23 = 17.5 Ch.24 =
RMS LOG ERROR: 2.29E-02, ANTILOG YIELDS 5.4210 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.98		
P 2	-0.02	0.89	
T 1	0.00	0.00	1.00